Soil Strength and Shallow Tillage for Hard Layers over Buried Microirrigation Laterals

W. J. Busscher*, C. R. Camp, and P. J. Bauer, Coastal Plains Soil, Water, and Plant Research Center, 2611 W. Lucas St., Florence, SC, USA, 29501-1242. busscher@florence.ars.usda.gov, camp@florence.ars.usda.gov, and bauer@florence.ars.usda.gov

ABSTRACT

In a previous study, soil compaction limited cotton (*Gossypium hirsutum*) growth when production included no-tillage and irrigation with subsurface drip laterals on a loamy sand (Aquic Hapludult). To alleviate compaction and provide a suitable rooting environment, we evaluated two conservation tillage tools that disrupted the soil above the subsurface irrigation laterals. Subsurface laterals were placed either under every row or under alternate mid rows, both buried to a 30-cm depth. Tillage treatments, for each lateral placement, included no-tillage, 20-cm deep strip tillage with an in-row subsoil shank, and 15-cm deep broadcast shallow tillage with a stubble-mulch implement. Non-irrigated treatments included no-tillage and 30-cm deep in-row subsoiling. Soil cone index measurements revealed that tillage tools loosened the soil but compacted zones remained above buried laterals. Loosening the soil did not improve yields. Irrigation improved yield because both 1998 and 1999 were dry years. Deeper loosening is desirable but this may increase the potential of damaging buried laterals.

INTRODUCTION

Three factors, sandy soils with low water holding capacity (5 - 10 days), short periods of drought (5 - 20 days), and shallow, subsurface, hard, structureless, root-restricting layers, combine to cause severe water stress and low yields in southeastern Coastal Plain soils. A root restricting layer can be found in many southeastern Coastal Plain soils at a 20- to 40-cm depth (Busscher *et al.,* 1986). Sandy soil above the layer may hold only 2.5 cm of water, which is not enough to supply water to plants during frequent short droughts that occur seasonally (Sadler and Camp, 1986).

Producers commonly increase the water supply for plants with deep tillage. Deep tillage loosens the soil down to horizons that have structure and a greater water holding capacity, both of which can encourage root growth. However, deep tillage is required annually (Threadgill, 1982; Busscher *et al.,* 1986) or seasonally (Frederick *et al.,* 1998) because soils reconsolidate. Furthermore, deep tillage is expensive because it requires large tractors (14-20 kw per deep tillage shank), 20 to 25 l of fuel per hectare, and 20 to 40 min labor per hectare (Karlen *et al.* 1991). Less expensive, more permanent, alternative solutions are desirable

Buried microirrigation laterals have been successfully used in the southwestern US to provide water to cotton (Tollefson 1985; Henngeler, 1995). Buried laterals have also been used for a number of crops in the southeastern Coastal Plains (Camp *et al*., 1998). However, soils above the laterals have consolidated into hard layers, probably compacted as a result of settling and traffic when laterals remain buried for several years (Camp *et al.,* 1999). A method for breaking up these hard soils above the laterals, without disruption of the laterals needs to be developed.

We hypothesised that disruption of the soil by shallow tillage tools would loosen the soil above the buried laterals to the extent that it would permit better root growth improving yield.

MATERIALS AND METHODS

This study was conducted in 1998 and 1999 on a Eunola loamy sand (Aquic Hapludult) at the Pee Dee Research Center near Florence, SC. Plots were 8 m by 15 m. Plots were planted to a soybean (*Glycine max* L. Merr.) and cotton rotation, where soybean were drilled in 19-cm rows and cotton planted in 96-cm rows. One set of plots was planted to soybean while the other was planted to cotton, both following winter fallow.

The experimental design was randomized complete block of sixteen plots (eight for each part of the rotation) in each of four replicates. Six of the eight plots were irrigated with buried microirrigation laterals (Geoflow Rootguard[1]). Laterals had in-line labyrinth emitters 0.6 m apart that delivered 1.6 l hr^{-1} of water at a pressure of 140 kPa. Three plots had laterals buried under each of eight rows at 1-m spacings. Three plots had laterals buried under alternate mid rows at 2-m spacings. Laterals were buried to 0.3-m depths. Two plots had no irrigation.

For each lateral spacing, treatments imposed on individual plots were no tillage and shallow tillage with the Beasley and Stubble Mulcher implements. For the two plots with no buried laterals, treatments imposed were conventional subsoiling and no tillage. The Beasley

[1] Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

was a prototype implement (Naderman, 1993) with forward angled, straight shanks that were adjusted to till 20-cm deep. The Stubble Mulcher (Roll-A-Cone Mfg. Co, Tulia, TX) had 110-cm wide sweeps that were adjusted to overlap and run at a 15-cm depth for complete, shallow loosening. Conventional subsoiling was performed with the KMC subsoiler (Kelley Mfg. Co, Tifton, GA) with shanks set at row widths, 96 cm, and run at a depth of 40 cm. Tillage was performed on 12 May 1998 and 5 May 1999. No other tillage was performed in the plots.

In plots with buried laterals, the recommended practice for this soil, annual in-row subsoiling, would not be practical because it may destroy the laterals themselves or the feeder or drain lines at the ends of each lateral. In 1991, prior to the installation of the laterals, all plots were cross subsoiled parallel and perpendicular to the direction of the rows (Camp *et al.*, 1999).

Cotton (Delta Pine ACALA90 in 1998 and NuCotn33B in 1999) was planted to 13 plants per meter on 13 May 1998 and 10 May 1999 and harvested 29 September 1998 and 22 October 1999. The same wheel tracks were maintained throughout the study as much as possible. Pesticide and fertilizer were applied as recommended by the South Carolina Cooperative Extension Service (Clemson University, 1982).

Soil strength measurements were taken in the cotton plots only. Soil strength measurements were taken after tillage before irrigation started. Data could not be collected at specific locations without puncturing buried laterals in the rows or in the mid rows. Therefore, measurements for the two lateral placement treatments were combined to give one set of readings. This combination permitted data analysis across the whole plot regardless of placement.

Soil strength data, measured as cone index, were taken with a 12.5-mm-diameter cone-tipped penetrometer (Carter, 1967) on 21 May 1998 and 27 May 1999. Cone indices were measured by pushing the penetrometer into the soil to a depth of 55 cm at nine positions spaced 12-cm apart starting at the middle of the plot and moving outward, excluding the position of the lateral where appropriate. Cone index data were digitized into the computer at 5-cm depth intervals and log transformed before analysis according to the recommendation of Cassel and Nelson (1979). Data for all positions across the plot and depth were combined to produce cross-sectional contours of soil cone indices using the method of Busscher *et al.* (1986).

Gravimetric soil water content samples were taken along with cone indices. They were taken at the first and fifth positions of cone index readings. Water contents were measured at 10-cm depth intervals to the 60-cm depth. These water contents were taken as representative of the water contents of the plot.

We analyzed cone index and water content data using ANOVA and the least square mean separation procedures (SAS Institute, 1990). Data were analyzed using a split-split plot randomized complete block design where the first split was position across the row and the second was depth. Data were tested for significance at the 5% level of probability.

RESULTS AND DISCUSSION

Soil Water Content

Differences in soil water contents can affect cone index readings, masking strength differences in treatments. To avoid this we took cone index measurements before irrigation began while the soil was still moist from winter rains.

For both years, the only water content differences were among depths. Soils were moist near the surface, slightly dryer under that, and increased in water content with depth below that. On a dry weight basis, values averaged over the two years were 0.10 g/g at 5-cm depth, 0.09 g/g at 15 cm, 0.09 g/g at 25 cm; 0.10 g/g at 35 cm; 0.12 g/g at 45 cm, and 0.14 g/g at 55 cm (LSD at 5% = 0.01).

Soil Strength

Cone indices were not different between years for any of the factors considered. In fact, cone indices were similar for the two years with average values of 3.17 MPa (1.515[2]) for 1998 and 3.19 MPa (1.517, LSD at 5% = 0.03) for 1999. Because of these similarities, data for the two years were combined.

Mean profile cone indices were different for treatments in the order of 3.71 MPa (1.580) for no tillage without buried laterals, 3.41 MPa (1.546) for no tillage with buried laterals, 3.20 MPa (1.518) for tillage with the Beasley, 3.01 MPa (1.493) for tillage with the subsoiler, and 2.80 MPa (1.462, LSD at 5% = 0.045) for tillage with the Stubble Mulcher.

The no-tillage with buried laterals treatment (Fig. 1) showed high strength built up in the upper part of the profile since the plots were cross subsoiled when laterals were first buried six (for 1998 readings) or seven (for 1999 readings) years earlier. High cone index measurements could easily restrict root growth, especially when considering root restricting values measured at 2 MPa (Taylor and Gardner, 1963; Blanchar *et al.*, 1978). In this treatment, the 2 MPa contour was approximately 5 cm from the surface. This helped explain shallow rooting noted in the earlier experiment using these plots (Camp *et al.*, 1999). The fact that this contour was so far above the buried laterals may also limit the effectiveness of irrigation.

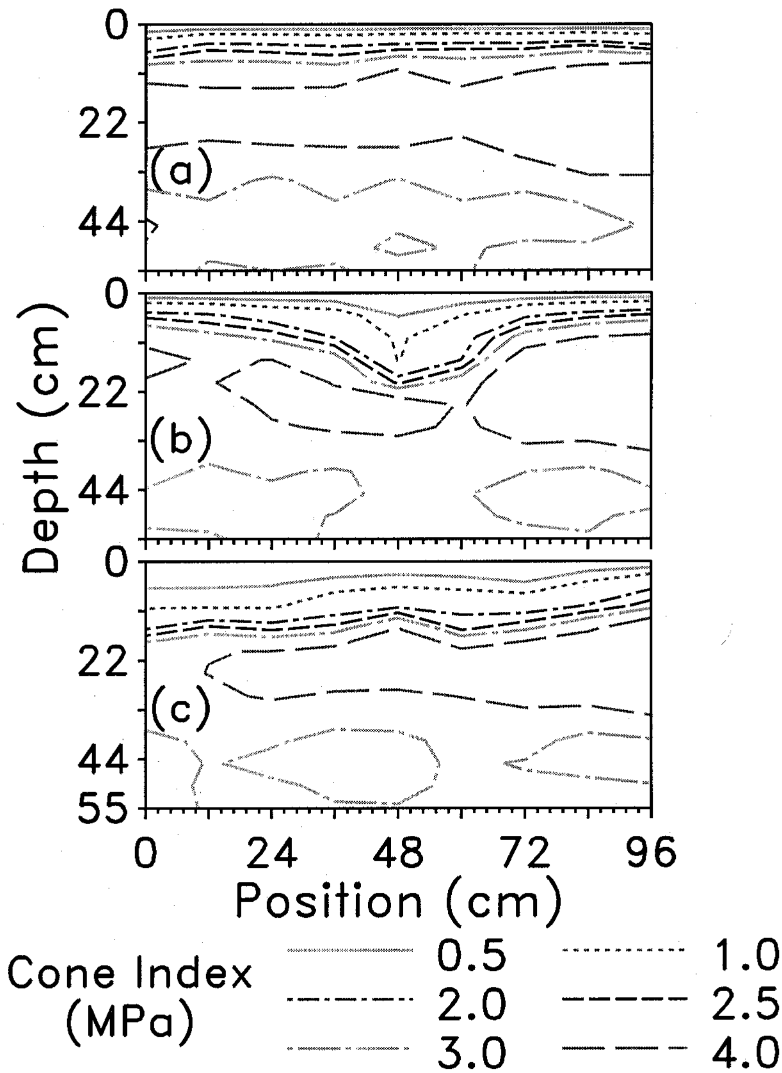

Figure 1. Soil cone index contours for plots with laterals and tillage treatments of (a) no tillage, (b) tillage with the Beasley, and (c) tillage with the Stubble Mulcher.

---

[2]Since analyses were performed on a log transform, numbers in parentheses are log base 10 of the cone indices +0.1. The addition 0.1 prevented us from taking log(0).

Conventional management of the high strength problem could be seen in the non-irrigated treatment tilled with the subsoiler (Fig. 2). Here a zone below the row was loosened to permit root growth through the hard layer into the lower horizons that had structure and can support root growth even at the higher strengths.

Reconsolidation of the loosened zone was seen in the non-irrigated no-tillage treatment (Fig. 2). This treatment had been subsoiled one (for 1998 readings) or two (for 1999 readings) years earlier. Yet, the 2 MPa contour was at about the same depth as for the treatment that had not been subsoiled for six or seven years. Reconsolidation to higher strengths was not as complete; but when compared to the subsoiled treatment, it was evident that higher consolidation was occurring.

Deep tillage was not practicable in plots that had buried laterals. Since high strengths developed above the laterals and since the laterals can function in these soils for at least 10 y (Camp *et al.*, 1995), some form of loosening above the laterals was desirable. Loosening with the Beasley and Stubble Mulcher was intended to lower cone indices above the laterals, permitting root growth to the irrigation water. Neither implement loosened the soil below cone indices of 2 MPa to the depth of the laterals (30 cm). Both had zones of high strength above the laterals.

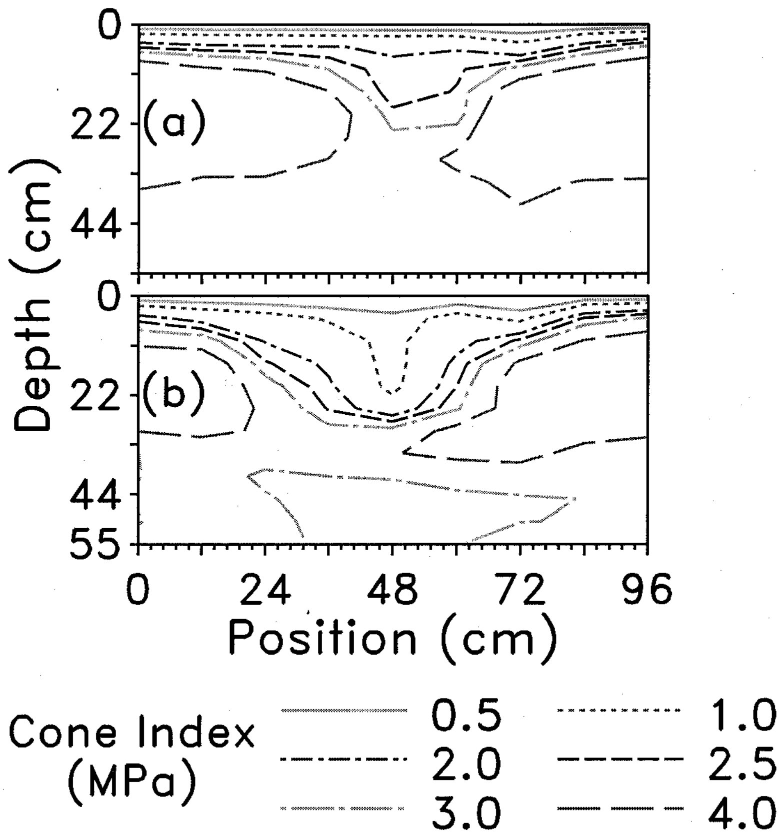

Figure 2. Soil cone index contours for the non-irrigated plots with tillage treatments of (a) no tillage and (b) subsoiling.

Acting as a shallow subsoil shank (Fig. 1), the Beasley disrupted a shallow compacted zone below the row. However, this disruption was only about 20-cm deep. The mean profile cone index for the treatment tilled with the Beasley was not significantly lower than for the non-tilled treatment with laterals.

The mean profile cone index for the Stubble Mulcher was lower than the no-tillage treatments. However, the low cone indices were distributed evenly near the surface of the soil (Fig. 1). High strength soil still remained for 10 cm or more above the laterals. This disruption pattern was similar to, though deeper than, that for disking, as seen in earlier work (Busscher et al. 1986).

Yield

Briefly, as described by Camp and coauthors (2000), irrigation was effective in increasing yield (958 kg/ha) over non-irrigated plots (621 kg/ha, LSD at 5% = 139) at least partly because both years were dryer than normal. This showed that irrigation water was able to migrate upward to help soften the hard layer and to provide water for the roots. None of the tillage was effective in increasing yield. For the irrigated plots, this ineffectiveness probably means that either tillage did not disrupt enough of the hard layer to be effective or irrigation water effectively migrated up to the roots.

CONCLUSIONS

Soil above subsurface laterals hardened to strengths that were root restricting, limiting yield potential. Tilling the soils above the laterals was effective in loosening the soil in the row for the Beasley or broadly across the surface for the Stubble Mulcher. Yields were not increased by this loosening. Loosening was not effective because hard layers still existed above the buried laterals. Providing more complete loosening above the laterals would probably be necessary to increase yield. More complete loosening has been effective in increasing yield in other studies on these Coastal Plain soils (Sojka *et al.*, 1991). This loosening will be difficult to accomplish while still insuring that laterals will not be damaged by tillage implements. Non-subsoiled and subsoiled non-irrigated treatments did not differ in yield. It is possible that this subsoiling was also not deep enough or that some other factor limited yield.

REFERENCES

Blanchar, R. W., Edmonds, C. R., Bradford, J. M. 1978. Root growth in cores formed from fragipan and B2 horizons of Hobson soil. Soil Sci. Soc. Am. J. 42, 437-440.

Busscher, W. J., Sojka, R. E., Doty, C. W. 1986. Residual effects of tillage on Coastal Plain soil strength. Soil Sci. 141, 144-148.

Camp, C. R., Bauer, P. J., Busscher,W. J. 1999. Evaluation of no-tillage crop production with subsurface drip irrigation on soils with compacted layers. Trans ASAE 42(4), 911-917.

Camp, C. R., Bauer, P. J., Busscher,W. J. 2000. Subsurface drip irrigation and conservation tillage methods for cotton on a soil with compacted layers. Proc. National Cotton Conference Beltwide Conf. (in press).

Camp, C. R., Bauer, P. J., Hunt, P. G., Busscher, W. J., Sadler, E. J. 1998. Subsurface drip irrigation for agronomic crops, pp. 49-53. In Proc. Int'l Irrigation Show and Technical Conference, 1-3 Nov., San Diego, CA.

Camp, C. R., Sadler, E. J., Busscher, W. J., Sojka, R. E., Karlen, D. L. 1995. Experiences with microirrigation for agronomic crops in the southeastern USA, pp. 638-644. In Microirrigation for a Changing World: Conserving Resources / Preserving the Environment. F.R. Lamm (ed). Proc. of the 5th Int'l Microirrigation Congress 2-6 April 1995, Orlando, FL.

Carter, L. M. 1967. Portable penetrometer measures soil strength profiles. Agric. Eng. 48, 348-349.

Cassel, D. K., Nelson, L. A. 1979. Variability of mechanical impedence in a tilled one hectare field of Norfolk sandy loam. Soil Sci. Soc. Am. J. 43, 450-455.

Clemson University. 1982. Lime and fertilizer recommendations based upon soil test results. Cooperative Extension Service Cir. #476, Clemson, SC.

Frederick, J. R., Bauer, P. J., Busscher, W. J., McCutcheon, G. S. 1998. Tillage management for doublecropped soybean grown using narrow and wide row-width culture. Crop Sci. 38, 755-762.

Henggeler, J. C. 1995. A history of drip-irrigated cotton in Texas, pp. 669-674. In Proc. Fifth Int'l Microirrigation Congress, ed F.R. Lamm, St. Joseph, MI: ASAE

Karlen, D. L., Busscher, W. J. Hale, S. A., Dodd, R. B., Strickland, E. E., Garner, T. H. 1991. Drought condition energy requirement and subsoiling effectiveness for selected deep tillage implements. Trans. ASAE 34, 1967-1972.

Naderman, G. 1993. Equipment considerations for reduced-tillage cotton production in the southeast, pp. 13-17. Arkansas Agric. Expt. Sta. Special Report 160.

Sadler, E. J., Camp, C. R. 1986. Crop water use data available from the southeastern USA. Trans. ASAE 29, 1070-1079.

SAS Institute Inc. 1990. SAS/STAT User's Guide, Vol. 2, SAS. Inst. Inc., Carey, NC.

Sojka, R. E., Karlen, D. L., Busscher, W. J. 1991. A conservation tillage research update from the Coastal Plain Soil and Water Conservation Research Center of South Carolina. Soil Tillage Res. 21, 361-376.

Tollefson, S. 1985. the Arizona system: Drip irrigation design for cotton. In Proc. third Int'l Drip/Trickle Irrigation Congress 1, 401-405. St. Joseph, MI: ASAE.

Taylor, H. M., Gardner, H. R. 1963. Penetration of cotton seedling taproots as influenced by bulk density, moisture content, and strength of the soil. Soil Sci. 96, 153-156.

Threadgill, E. D. 1982. Residual tillage effects as determined by cone index. Trans. ASAE 25, 859-863.